# EXPERIMENTAL ANALYSIS ON WATER PIPE TURBINE-GENERATOR DESIGN PARAMETERS

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## ABSTRACT

The objective of the study is to develop a small-scale water pump based test bed and to do prototyping of various turbine designs based on various parameters. As the energy demand of industry grows exponentially, fabrication of hydraulic energy system becomes a crucial point of concern. Many research activities about hydraulic have been carried out by experimental methods and by theory and simulation. Hydro energy parameters have been used to study the relation between the hydro energy parameters and subsequent relative output energy. The results obtained by the experimental results, performed in prototype model. In this work different parameters have been used to tap water. The water injected by nozzle on blades of hydraulic turbines. Efficiency and maximal power output are two of the most important goals to analyze in hydraulic turbines. The efficiency of water turbines are most frequently expressed using the power output at the alternator. To perform the calculation of efficiency is necessary to know several parameters such as kinetic and potential energy of water due to the position, because of this is required to know the flow rate entering the turbine. The flow rate of water through the turbine (Q) is determined by the volume of water flowing in time unit. As a conclusion, this project is quite successful because it is able to fulfill all of the objectives stated and also performing up to expectation.

# ABSTRAK

Objektif kajian adalah untuk membentuk sebuah pam air berasaskan ujian kecil-kecilan dan untuk melakukan prototaip daripada pelbagai reka bentuk turbin berdasarkan pelbagai parameter. Sebagaimana permintaan tenaga industri tumbuh dengan pesat, pembikinan sistem tenaga hidraulik merupakan hal penting yang membimbangkan. Banyak aktiviti-aktiviti penyelidikan mengenai hidraulik telah dijalankan dengan kaedah eksperimen dan teori dan simulasi. Parameter tenaga hidro telah digunakan untuk mengkaji hubungan antara parameter tenaga hidro dan seterusnya tenaga output relatif. Keputusan yang diperolehi oleh keputusan eksperimen telah dilakukan dalam model prototaip Dalam eksperimen ini, parameter yang berbeza telah digunakan untuk air paip. Air disuntik oleh muncung pada bilah turbin hidraulik. Kecekapan dan output kuasa maksimum adalah dua matlamat yang paling penting untuk menganalisis dalam turbin hidraulik. Kecekapan turbin air yang paling kerap dinyatakan menggunakan output kuasa pada alternator. Untuk melakukan pengiraan kecekapan adalah penting untuk mengetahui beberapa parameter seperti tenaga kinetik dan potensi air kerana kedudukannya, kerana ini diperlukan untuk mengetahui kadar aliran yang memasuki turbin. Kadar aliran air melalui turbin (Q) adalah ditentukan oleh jumlah air yang mengalir di dalam unit masa. Kesimpulannya, projek ini amatlah berjaya kerana semua objektif berjaya dicapai dan mesin prototaip yang terhasil berfungsi pada tahap yang memuaskan.

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| | |
|---|---|
| $A$ | Area |
| $d_s$ | Diameter of nozzle |
| $g$ | Gravity |
| $H$ | Head |
| $P$ | Power Output |
| $t$ | Time |
| $v$ | Velocity |
| $V$ | Volume |
| $z$ | Number of Nozzle |
| $\rho$ | Density of Water |
| $\eta$ | Efficiency |
| $\pi$ | pi |

# LIST OF ABBREVIATIONS

| | |
|---|---|
| AC | Alternating Current |
| CNC | Computer Numerical Control |
| DC | Direct current |
| FDTA | Fundacion Desarollo de Technologias Appropiades |
| PVC | Polyvinyl chloride |
| RPM | rotation per minute |
| SMAW | Sheet Metal Arc Welding |

# CHAPTER 1

# INTRODUCTION

## 1.1 BACKGROUND STUDY

A turbine with a low-cut in speed is needed to get maximum energy from the marine current. The velocity and density of flowing bodies determine the kinetic energy that can be converted into mechanical energy using turbine. The kinetic energy of water current can be converted into mechanical energy using turbine. The mechanical energy is then transferred through a drive shaft to operate a machine, compressor, electric generator or propeller. By using small water turbines fed from river or type tap water, individuals can gather consistent power, no matter how far from the utility power grid they may be. The basic elements in a turbine are wheel or rotor with paddles, propellers, blades or buckets (Ajuwape and Ismail, 2011). Water turbine design parameters can be in many ways such as turbine type, direction of water in and water out.

## 1.2 PROBLEM STATEMENT

Since the industrial revolution begun in $18^{th}$ century, fuel has become one of the vital energy in our life. However the amount of non-renewable fuels such as gasoline is shrinking day by day and will eventually depleted at the end. In order to ensure having the sufficient alternatives energy is hydropower which uses hydroturbines or water turbines to generate electricity or power. The turbine is use to convert energy from water to shaft power which drive to generator or alternator.

The type of blades, number of blades will affect the power output and efficiency of turbines. So, the correlation between the design parameters and the efficiency of the output shaft rotating speed will be identifying.

## 1.3 OBJECTIVES

The objectives of the study are:

a. To develop a small-scale water pump based test bed.
b. To do prototyping of various turbine designs based on various parameters.

## 1.4 SCOPES

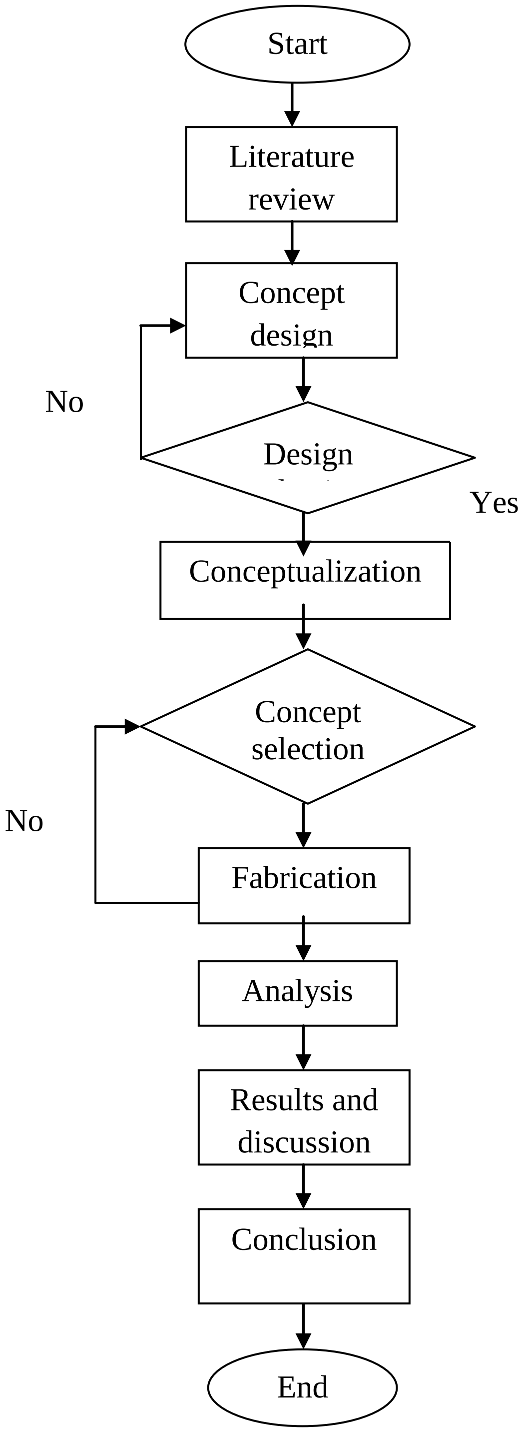
This project development is limited within the following scopes:

a. Benchmarking on water turbine blades design and types.
b. Selection of turbine blade design parameters and actual prototyping.
c. Experimental setup for efficiency setting.

## 1.5 HYPOTHESIS

The hypothesis for this experimental are size of buckets will affect the rotation of blade and velocity of nozzle very important to have higher rotation of blade.

## 1.6 FLOW CHART




## 1.7 GANTT CHART

The Gantt chart is attached in Appendix A

# CHAPTER 2

# LITERATURE REVIEW

## 2.0 INTRODUCTION

In this chapter, information about hydropower and hydroturbine are discussed. The sources of the review are extracted from journals, articles, books, reference books and internet. The purpose of this section is to provide additional information and relevant facts based on past researches which related to this project.

## 2.1 ADVANTAGES OF HYDROPOWER

Hydropower is the energy from moving water, is one of the oldest renewable energy sources and the total global electric power of hydropower, including large hydropower, small hydropower and ocean. However, small hydropower has been increasingly used as an alternative energy source so that a small system is installed in small rivers or streams with little environmental effect.

According to research made by The British Hydropower Association, small hydropower has efficiency of 70-90%, so far the best compared to wind and solar power. Higher efficiency will improve the performance of electricity generation. The research also proved that high capacity factor of micro hydro power (typically >50%), compared with 10% for solar and 30% for wind. Furthermore, small hydro has high predictability depends on the rainfall patterns. The flow and velocity of rives changes slowly from day to day. These slow rate changes make the output of the hydro power changes gradually.

Small hydropower is a long lasting and robust technology. The system can be used as long as 50 years or sometimes more. Small hydro power also always follows the demand, during winter the output is maximum. This is a good correlation with demand. Small hydropower is environmental friendly where it does not affect the natural ecosystem. No reservoir required for micro hydro because it based on run-of-river system.

Small hydropower systems allow achieving self-sufficiency by using the best as possible the insufficient natural resource such as water, as a decentralized and low-cost of energy production. Hydropower is the most important energy source in what concerns no carbon dioxide, sulphur dioxide, nitrous oxides or any other type of air emissions and no solid or liquid wastes production. This system produces a cleaner energy system. It also saves the consumption of fossil, fuel and firewood (Ramos, 1998).

## 2.2 HYDROTURBINES

Water turbine can be classified by the type of generator used or the water resources in the installed place. A water-head turbine is the most generally used system, and this makes the turbine rotate by converting the potential energy of water into kinetic energy. Hydro systems that have two terms that will be used are head and flow. The head pressure is determined by the vertical distance the water falls. Meanwhile flow is the quantity of water flowing given period of time. This water turbine has the advantage of high efficiency, but the construction cost for a dam or waterway is high and can cause significant environmental problems.

Selection of turbine that to be used in design and development of a hydro power system is very important. Table 2.1 show that the group of impulse and reaction turbines that are available. Reaction turbine is fully immersed in water and enclosed in a pressure casing. The runner or rotating element and casing are carefully engineered so that the clearance between them is minimized. Meanwhile, impulse turbine can operate in air and works with high-speed jet of water. Usually, impulse turbines are cheaper than reaction turbines because no specialist pressure casing and no carefully engineered clearance are needed (Harvey, 1993).

**Table 2.1:** Group of Impulse and Reaction Turbines

| **Turbine Runner** | **Head Pressure** | | |
|---|---|---|---|
| | **High** | **Medium** | **Low** |
| Impulse | Pelton<br>Turgo<br>Multi-jet pelton | Crossflow<br>Turgo<br>Multi-jet Pelton | Crossflow |
| Reaction | | Francis<br>Pump-as-turbine | Propeller<br>Kaplan |

Source: Harvey (1993)

Pelton turbine is commonly used in a small scale hydro power system due to its suitability that used jet water (Maher, 2001). One of convenient methods for selecting a turbine for particular hydro system is given in Figure 2.1 (Harvey, 1993). The turbine type is selected based on the speed range and power capacity of alternator that is to be used. Pelton turbine is universal turbine because it is not restricted to high head, but it depends on power transmitted.

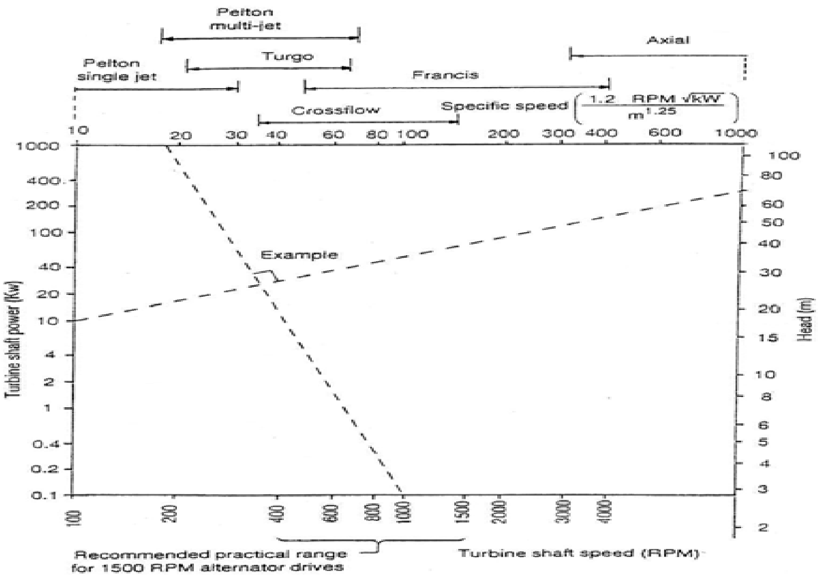



**Figure 2.1**: Nomogram for Selection of A Turbine For Hydro Site

Source: Harvey (1993)

## 2.3 PARAMETERS OF HYDROPOWER

### 2.3.1 Head

Head of flow is the vertical fall of water flow from higher to lower lever due to potential energy. For example river passes a waterfall. Head is an important parameter of hydropower. The head affect the flow rate of the flow. Head of flow can be determined by measuring the flow from the highest point to the lowest water drop. The unit of head is in meter (m). It is generally better to have more head than more flow (British Hydropower Association, 2005).

### 2.3.2 Flow Rate

Flow is the quantity of water moving past a given point over a set time period (cubic meters per second ($m^3/s$). More water falling through the turbine will produce more power. The amount of water available depends on the volume of water at the source. Power is also 'directly proportional' to river flow, or flow volume. The flow rate is the product of volume and area (Zubaidi, 2010) is expressed as in Eq. (2.1). The volume flow rate also can determine by using volume and time is expressed as in Eq. (2.2).

$$Q=vA\ (m^3/s) \tag{2.1}$$

$$Q= V/t\ (m^3/s) \tag{2.2}$$

### 2.3.3 Power and energy

The amount of power available from a micro hydro generator system is directly related to the flow rate, head and the force of gravity. Once we have determined the usable flow rate (the amount of flow we can divert for power generation) and the available head for our particular site, we can calculate the amount of electrical power we can expect to generate (Zubaidi, 2010). Power is expressed as in Eq. (2.3)

$$P = \rho gHQ \tag{2.3}$$

## 2.4 TURBINE EFFICIENCY

Efficiency is defined as a level of performance that describes a process that uses the lowest amount of inputs to create the greatest amount of outputs**.** For hydropower, the efficiency and performance of the plant mainly depends on the types of turbine used. Turbine selection is depending on the scale of hydropower and the location to install the turbine. Efficiency is affected by the Head (H), flowrate (Q), density of water (ρ) and gravitational constant.

Comparison between few turbines is made to determine the higher performance turbine. An important point to note is that the Pelton and Kaplan turbines retain very high efficiencies when running below design flow; in contrast the efficiency of the Crossflow and Francis turbines falls away more sharply if run at below half their normal flow. Most fixed-pitch propeller turbines perform poorly except above 80% of full flow (British Hydropower Association, 2005) shows in Figure 2.2.

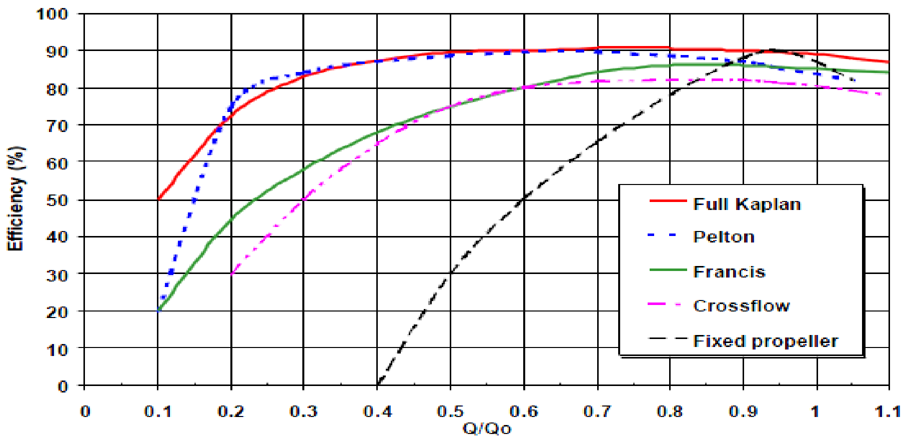



**Figure 2.2:** Turbine efficiency

Source: British Hydropower Association (2005)

The efficiency of turbine can be calculated using the following Eq. (2.4)

$$P = \eta \text{ x } \rho \text{ x } g \text{ x } H\text{net x } Q \qquad (2.4)$$

Table 2.2 show the turbine efficiency with different type of turbines.

**Table 2.2:** Turbine Efficiency

| Turbine | $\eta$ |
|---|---|
| Pelton | 0.90 |
| Banki-Mitchell | 0.87 |
| Turgo | 0.85 |
| Francis | 0.90 |
| Kaplan | 0.90 |

Source: Johnson (2008)

## 2.5 PICO-HYDRO POWER GENERATION CASE STUDY

### 2.5.1 Peltric Set

The ‘Peltric Set’ was developed at Kathmandu Metal Industry in Nepal and is shown in Figure 2.3. A vertically mounted induction generator is directly couple to a Pelton turbine. The turbine casing also forms the base for the generator which makes the design simple and economical with material. AC electricity is generated which means that the power can be distributed economically over hundreds of meters. There is approximately 500 unit type electrifying villages in Nepal at present time.

**Figure 2.3:** The ‘Peltric Set has provided many rural villages with an economical electricity supply in Nepal.

Source: Lahimer (2011)

### 2.5.2 Columbian Alternator system

Columbian Alternator system has been designed at FDTA ( Fundacion Desarollo de Technologias Appropiades) in Colombia, South America. The turbine runner is also a small Pelton wheel but a 12V DC car or truck alternator is used as a generator. The turbine is couple to the alternator using a pulley belt and mounted on a simple steel-angle frame that is easy to manufacture. The installation of this design is shown in Figure 2.4.

**Figure 2.4**: A Colombian manufacturer installs a DC Pico-Hydro Generation system

Source: Lahimer (2011)

The turbine shaft of the system is horizontal; it is possible to run other machines with hydro-power in addition to the generator. It has been highlighted that this design has been used to provide the energy source for a mechanical refrigerator. No extra control system is required other than voltage regular which is already included with the alternator. Since Direct Current (DC) is generated, no frequency regulation is required but the electricity must be used close to or at the powerhouse. Pico Power Pack combines the low-cost steel angle base and horizontal shaft of the Columbian alternator unit with the simple design of a Pelton turbine directly driving an induction motor used with the Peltric Set.

### 2.5.3 Pico Power Pack

The 'Pico Power Pack' components are shown in Figure 2.5. The generator is mounted horizontally on a steel angle (Maher and Smith, 1999). Since AC (Alternating current) is generated, the system is suitable for electrifying houses that are up to one kilometre away from the powerhouse, like with the 'Peltric Set'. The removable case makes it easy to inspect the turbine and the nozzle and to clean them when necessary. The generator shaft is extended at the opposite end from where turbine is attached. This allows a pulley to be fitted. Small machines such as mills, grinding wheels or saws can be driven with a pulley. In this way, the hydro-power can be used for a wider range of productive purposes. The extra money made through running a small business using Pico-Hydro power, makes it easier to repay the cost of the scheme.

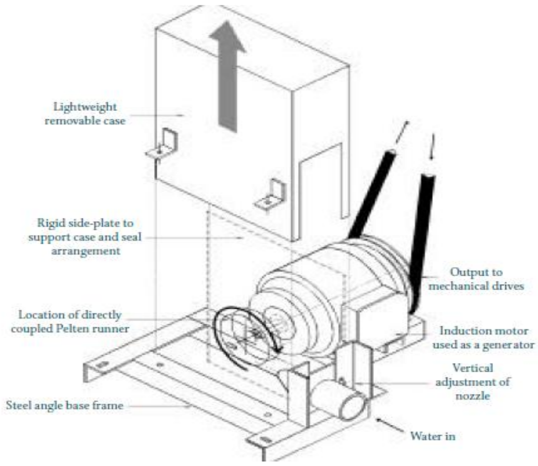



**Figure 2.5**: The Pico Power Pack generates AC electricity

Source: Maher and Smith (2001)

## 2.6 PELTON TURBINE

The water strikes the bucket along the tangent of the tangent of the runner. The energy available at the inlet of the turbine is only Kinetic Energy. The pressure at the inlet and outlet is atmospheric pressure. The nozzle increases the kinetic energy of the water flowing through the penstock. At the outlet of the nozzle, the water comes out in the form of a jet and strikes the buckets (vanes) of the runner. Typically, when using this type of turbine, water is piped down a hillside so that at the lower end of the pipe, it emerges from a narrow nozzle as a jet with very high to the turbine blades.

### 2.6.1 Main Parts of Pelton Turbines

According to Research made by Government Technological College Meiktila about Basic Design of Pelton Wheel Turbine, the main parts of Pelton Turbine are:

a. Nozzle and flow regulating.

The amount of water striking the buckets is controlled by providing a spear in the nozzle. The spear is a conical needle operated in the axial direction depending up on the size of the unit. When the spear is pushed forward, the amount of water striking the runner is reduced and when the spear is pushed back, the amount of water striking the runner increases.

Each half is turned backwards, almost through 180° relative to the bucket on a horizontal plane. Practically this angle may vary between 165° to 170°. Normally all the jet energy is used in propelling the rim of the bucket wheel (Mack, 2010).

b. Runner and Buckets

Runner consists of a circular disc on the periphery of which a number of buckets evenly spaced are fixed. The space of the buckets is of a double hemispherical cup or bowl. Each bucket is divided into two symmetrical parts by dividing wall which is known as Splitter. The buckets are made of cast iron, cast steel bronze or stainless steel depending upon the head at the inlet of the turbine.

c. Casing

The function of water is to prevent the splashing of water and to discharge water to tail race. The casing of Pelton Wheel does not perform any Hydraulic function.